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EOS

Earth & Space Science News

Broken Bridge Between Geology and Museums

Pharaoh's Dagger, Made from a Meteor

Marine Life in the Pacific Arctic

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Christine W. McEntee, Executive Director/CEO

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New Law Puts the Squeeze on the Arizona Geological Survey

A new law that consolidates the Arizona Geological Survey within the University of Arizona at Tucson could result in dramatic cuts to state geological services, according to the Survey and some industries that rely on its capabilities. However, Arizona governor Doug Ducey's office maintains that the cost-cutting action benefits taxpayers while building on synergy between the Survey and the university.

The action, part of broader budget legislation Ducey signed into law in May (see http://1.usa.gov/1Xe5M01), called for the Survey to vacate its current quarters by 30 June and move into space 75% smaller, but the law does not provide funding for the Survey for fiscal year (FY) 2017, which began on 1 July.

The University of Arizona has agreed to provide the Survey with the equivalent of the Survey's FY 2016 state appropriation of $941,000 for the upcoming fiscal year, after which the Survey would need to become entirely self-supporting, according to Lee Allison, Arizona state geologist and director of the Survey. Allison serves as a member of the *Eos* Editorial Advisory Board.

At risk is funding for mapping, hazard monitoring, and other services.

Reduction in Services

Since 2011 the Survey received $5.36 million from the state while entrepreneurially raising an additional $35.8 million through external research grants and contracts, according to a Survey document, which notes that the Survey had 27 employees earlier this year.

Allison applauded the University of Arizona for agreeing to replace state funds for the Survey for the coming year. However, he told *Eos* that the grant and contract funding that the Survey has raised on its own to support its state services now "will mostly go to the university to support [its] services, resulting in a 40%–50% reduction of those [Survey] functions and the staff that carried them out." He said that concerns about the Survey's future have prompted 20% of its staff to take other jobs. Allison also has notified another 25% of staff of pending layoffs.

The uncertainty of having only 1 year of assured funding for the remaining staff "puts the Survey's medium-term capabilities and functions at risk," he said. As the Survey transitions to a soft money grant-seeking center, Allison said that state service priorities, subsidized through indirect costs from grants and contracts, "could go by the wayside."

State services at risk include a program to map Earth fissures—giant tension cracks formed by subsiding basins—which developers and local planners depend on; the state's earthquake-monitoring network; and the Survey's mineral resources program, according to Allison.

Governor's Office Defends Action

The consolidation language, which was in the final state budget package approved in May, reflects a strategic way to cut the budget while taking advantage of synergies between the Survey and the university, according to Dan Scarpinato, spokesman for Governor Ducey. He said the consolidation is a cost-efficient "net positive" for the Survey and the clients it assists and for the university.

"Anytime you change something that's been operating one way for a very long period of time, there are going be concerns and there are going to be questions," he said, adding that the state wants to address concerns so that the consolidation works. With the budget approved, experts need to "come to the table and figure out how we combine these programs [and] make the consolidation work in a way that doesn't have an impact on the clients themselves or the services that are provided."

University of Arizona spokesman Chris Sigurdson reiterated to *Eos* what he told the *Arizona Daily Star* (see http://bit.ly/Sigurdson-AZ-Star)—that the transfer of the Survey to the university "makes scientific sense to us and is in line with our land-grant mission of service."

Consolidation Could Be "Devastating"

However, Doug Bartlett, president-elect of the Arizona chapter of the American Institute of Professional Geologists, said that moving the Survey to the university without a long-term funding mechanism "will be devastating to the Survey."

He told *Eos* that the move will result in a loss of primary research, field mapping, monitoring for geological hazards, and detailed geologic mapping useful to Arizona's minerals industries. "Private industry cannot and will not step in to replace what the Survey does," he said.

Steve Trussell, executive director of the Phoenix-based Arizona Rock Products Association, said that perhaps the biggest concern about the changes affecting the Survey is what might happen to mapping and other services it provides. He said, for instance, that the Survey's maps and other programs help the construction, real estate, mining, and natural resources–related industries.

By **Randy Showstack,** Staff Writer

Joseph Cook, AZGS

The consolidation threatens some important state programs including mapping Earth fissures. Pictured is Michael Conway, chief of the Geologic Extension Service at the Arizona Geological Survey, mapping Earth fissures in the Queen Creek area south of Phoenix, Ariz.

Pharaoh's Iron Dagger Made from a Meteorite, Study Confirms

When archaeologists first examined the mummy of King Tutankhamun in 1925, they found two beautiful daggers in the pharaoh's linen wrappings. One had a gold blade, and the other was made of iron. A new study confirms what archaeologists have long suspected: Artisans crafted King Tut's iron dagger from a meteorite.

The new analysis suggests that ancient Egypt came late to using iron on a large scale. What's more, that tardiness may have led to military defeats at the hands of rival civilizations that had already equipped their soldiers with iron weaponry.

More Precious Than Gold

Many ancient people valued iron more than gold. Because iron has a high melting point (1538°C), early smiths couldn't heat ore hot enough to extract iron, nor could they forge the iron into weapons. Ordinary people had to rely on "bronze, and previously copper [to make tools and weapons]. Gold and iron objects in that period were mainly for ornamental purposes—for gifts and so on," said Daniela Comelli, a materials scientist at the Polytechnic University of Milan in Italy, who is the lead author of the new study of the dagger.

Metalworkers commonly chose bronze, which is a copper-tin alloy, for making swords, spears, and tools, because its constituent metals were easier to mine, refine, and work with. However, the Egyptians had a source of iron that was easy to work with, although difficult to acquire: meteorites. Those extraterrestrial rarities contained iron plus other elements, including 10%–30% nickel. Even though craftsmen couldn't melt meteorites, they could hammer them into beads, or into weapons like Tutankhamun's dagger, Comelli said. Few iron objects from ancient times remain today, partly because of loss from corrosion.

> New analysis suggests that ancient Egypt came late to using iron on a large scale.

X-ray Fluorescence Reveals Blade Composition

In the new study, published in the May issue of *Meteoritics & Planetary Science* (http://bit.ly/Tuts-Dagger), Comelli and her colleagues describe how they used a portable X-ray fluorescence (XRF) instrument to examine the dagger at the Egyptian Museum of Cairo. The interdisciplinary team bombarded the knife with X-rays and looked at the radiation emitted by the metal in response. Each element in the blade gave off different wavelengths of radiation, allowing the scientists to determine its composition.

The results indicated that the dagger contains substantial amounts of nickel and cobalt. Interpretation of the XRF measurements by scientists at the University of Pisa in Italy showed that the dagger's composition matched well with the compositions of 11 iron-bearing meteorites analyzed in the same way. To confirm the validity of the instrument's measurements, the team also used the device to analyze 11 samples of stainless steel with known percentages of constituent elements.

Previous studies have shown that iron made from mined iron ores prior to the 19th century contains less than 4% nickel, by weight. The team measured more than 10% nickel in the dagger, providing further evidence that it was made from meteorite metal rather than terrestrial ore.

This dagger, recovered from King Tutankhamun's mummy, consists of a rock crystal pommel, a golden hilt, and a blade hammered from meteoritic iron. Most iron objects from this era are heavily corroded, but the dry conditions in Tutankhamun's tomb kept the dagger rust-free.

Egyptian Museum of Cairo

In 1994, another team used X-ray fluorescence, which leaves the blade unharmed, to ascertain King Tut's dagger's composition. The dry conditions in Tutankhamun's tomb, which prevented the dagger from rusting, made it possible to use the technique for analyzing the composition of the blade's still-pristine surface. Researchers have shunned using any sort of destructive techniques to analyze the composition of the precious object.

The 1994 analysis concluded that the metals in Tutankhamun's blade did not match those in most iron meteorites. However, Comelli and her collaborators report in their paper that they used a newer, more accurate instrument to retest the blade.

"No one ever really doubted the meteoritic origin of that dagger," said Thilo Rehren, an archaeometallurgist at University College London, Qatar, in Doha, who was not involved with the study. "It was the logical thing to assume. The beauty of this [new] paper is that they've put it beyond doubt that this is meteoritic iron," he added.

Iron Still Rare in King Tut's Egypt

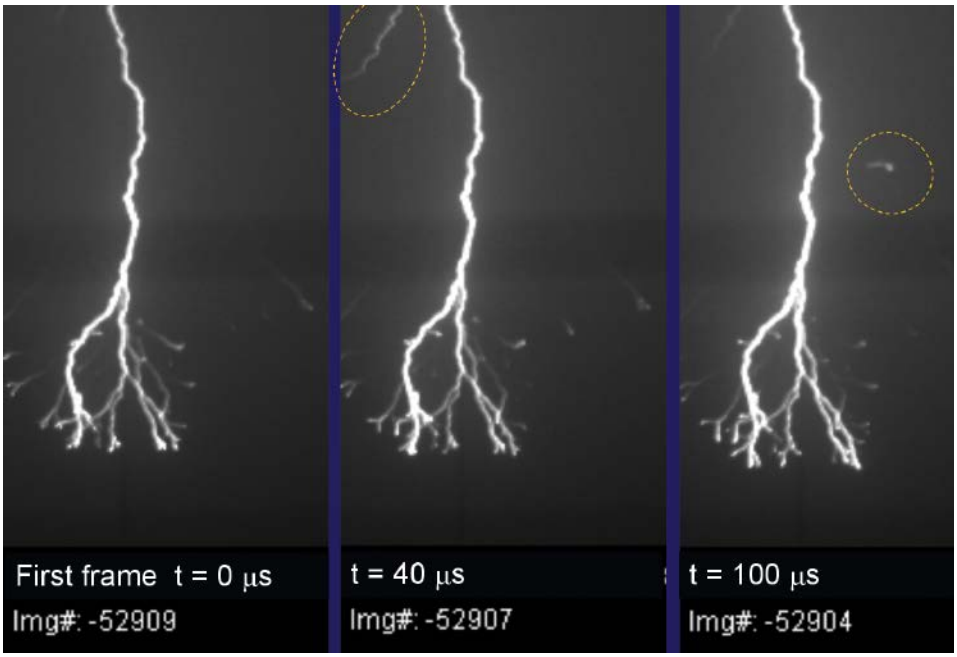
The new results strengthen historians' long-held suspicion that during Tutankhamun's short reign (1332–1323 B.C.E.), Egypt had yet to smelt and forge its own iron, Rehren said. Ancient Egyptians and neighboring cultures already referred to all kinds of iron at the time as "iron of the sky," Comelli and her coauthors note.

Ancient Egypt was "rather slow to take up iron as the metal of choice," said Rehren, because Egypt lacked both iron deposits and large numbers of trees to fuel smiths' fires. Iron weapons and tools in Egypt did not become common until between 700 and 800 B.C.E. Egypt's slowness came at a price. Because iron weapons were harder and more durable, Egypt fell much more easily during battles with the Hittites and the Nubian Kingdom of Kush—both of which had issued iron weapons to their soldiers while Egypt was still using bronze, Rehren said.

Determining the origin of the dagger and other iron objects from ancient Egypt will help scientists build a broader picture of ancient metallurgy there and in neighboring regions, according to Rehren. Comelli added that she hopes to get permission from the Egyptian Museum of Cairo, where the dagger is kept, to probe the artifact to find out more about the meteorite from which it was made.

By **Elizabeth Deatrick,** Editorial Intern

Dead Lightning Branches Come Back to Life



Stolzenburg et al., 2015, doi:10.1002/2014JD022933

Dashed lines encircle the sparks lighting up on dead stepped leader branches.

The rise of high-speed video over the past several years has allowed scientists to study lightning in unprecedented detail. In one of the latest findings, researchers have documented fleeting flare-ups, which they've dubbed "sparks," that rekindle previously abandoned paths visited by jagged blazes of lightning plunging to Earth.

When cloud-to-ground lightning propagates, it doesn't take a straight path. Instead, it follows a zigzag channel through the air, known as a stepped leader, which forms after strong electric fields ionize gas molecules, creating a highly conductive plasma (see http://bit.ly/lightning-basics). The stepped leader—which is invisible to the naked eye but can be seen by sensitive high-speed video cameras—extends itself in segments about 50 meters long apiece, often changing direction and splitting into many ancillary branches because the conductivity of the air is not uniform. A similar channel simultaneously takes shape from below until the two meet. That's when a powerful upward current of electric charge, called the return stroke, surges through the channel, causing the dazzling flash we know as lightning.

Many of the branches that shoot off the main stepped leader trunk go dark before the leader reaches the ground. But sometimes these abandoned branches suddenly spark back on again, reconnecting to their parent, according to new observations from Maribeth Stolzenburg, an atmospheric physicist at the University of Mississippi in Oxford, and her colleagues.

Surprisingly Common Sparks

"It's a little surprising to us that no one has described these previously because we see them in all stepped leaders," Stolzenburg said. She presented her team's findings in late April at the meeting of the European Geosciences Union (EGU) in Vienna, Austria (see http://bit.ly/sparks-abstract). She also described the phenomenon last year in a paper in the *Journal of Geophysical Research: Atmospheres* (see http://bit.ly/sparks-JGRD).

The findings are based on data Stolzenburg and her colleagues collected at Kennedy Space Center in Florida during a fruitful 6-week field season in 2011. Because stepped leaders can't be re-created in rocket-triggered lightning experiments, researchers must go to a place where natural lighting is common.

"In 2011 we had storms probably 3 out of 5 days, so it was a pretty active spot," Stolzenburg said of her field site. "We pretty much filled the camera memory every time we ran it." That's perhaps not so surprising, considering that just one trigger of their high-speed camera, recording at 50,000 frames per second, could create a file as large as 18 gigabytes.

In total, the team recorded 34 stepped leader systems from a maximum distance of 15 kilometers. The scientists reported that all 34 of these stepped leaders had at least one and as many as 15 visible sparks.

Examining the Flash

Because the high-speed video could capture changes along the lightning's path as brief as 20 microseconds, the observers could distinguish sparks from stepped leader branches still growing or just brightening or dimming, Stolzenburg told *Eos*. "These are really features that have stopped propagating and are basically abandoned," she added. "There's probably lots and lots of these that never light up as sparks, but the few that do are pretty prominent features."

Stolzenburg and her colleagues suspect that sparks occur when the potential difference, or voltage, across the gap between the cutoff branch and the active leader becomes strong enough to suddenly discharge.

The existence of sparks could help researchers make sense of some lightning observations that have never really had good explanations, Stolzenburg said. For example, sparks might explain why the lowermost tips of some stepped leaders suddenly accelerate as they get closer to the ground. When a spark occurred, the researchers observed that the parent leader zoomed faster, sometimes by as much as 109%.

This acceleration became especially apparent when a spark reconnected to a stepped leader and the leader suddenly beat a competing leader to the ground. The researchers also saw that the parent leader to which a spark reconnected would brighten by 5%–50% below the reconnection point.

As Seen in New Mexico

The research "certainly says something new about lightning and how the leader stepping goes," Harald Edens, a lightning researcher at the New Mexico Institute of Mining and Technology in Socorro, who was not involved in the study, told *Eos*. "It says a little bit more about what the voltage potential is doing along the channel and how the charges are moving, which are really not very well understood."

Edens, who attended Stolzenburg's 18 April talk at EGU, thinks he has seen the same sparks in stepped leaders. He wrote about his observations—made with the high-speed cameras at the mountaintop Langmuir Laboratory for Atmospheric Research just west of Socorro—in his dissertation back in 2011. However, he hasn't published those findings in a journal.

"I was very happy to see that someone saw what I think is the same phenomenon that we have seen at Langmuir Lab," Edens said. "What she described was very similar to what we have seen. To me, it made total sense."

By **Megan Gannon,** Freelance Writer; email: megan.i.gannon@gmail.com

Humans Misread Wind Speeds, Skewing a Major Hazards Database

People may think they know how hard the wind is blowing, but science shows that they usually get it wrong. Researchers have known this for years (see http://bit.ly/Wind-2012), but a recent study seeks to quantify just how bad humans are at figuring out the speed of wind gusts without the aid of meteorological instruments.

The authors of the study seek to make other researchers more aware of human bias when using Storm Data, one of the largest publicly available storm databases. The study (http://bit.ly/Wind-Estimation), published in a recent issue of *Journal of Applied Meteorology and Climatology,* uses a large-scale statistical analysis of information from the database to investigate how widely storm reporters' estimates of wind speeds differ from measurements.

Pete

Trained storm reporters learn to use environmental cues, like these swaying trees, to determine wind speeds.

Potential for Bias?

Storm Data (http://1.usa.gov/1UauX0j) is an enormous set of measurements characterizing more than 50 years' worth of geophysical events, from tidal waves to tornadoes, compiled by the National Centers for Environmental Information (NCEI) in Asheville, N.C. People from blizzard climatologists to insurance company adjustors make use of the data—and thanks to a thorough collection and vetting process, the storm reports the database generates are generally considered reliable.

However, because Storm Data aims to collect as many data as possible, not all of the information comes from weather stations with calibrated instruments. Many of the entries in the database come from trained—or even untrained—storm reporters. These reporters must rely on environmental cues to make estimates of wind speeds and other measurements.

"When you're estimating it, there has to be some sort of basis for that estimate…whether a tree limb snapped, or whether there was siding ripped off a house,'" said Brenton MacAloney, the Storm Data program manager at the National Weather Service in Silver Spring, Md. "There has to be something other than, 'uh, I thought it was something around 50 knots.'" The database asks its reporters to make narrative accounts of the events to check that their numbers are within the realms of probability.

Still, many researchers have long doubted the accuracy of Storm Data's human reporters. "Everyone had assumed that [Storm Data was unreliable], but nobody had actually shown it," said Peter Miller, the lead author on the study and a meteorologist at the University of Georgia in Athens.

Testing Storm Reporters' Accuracy

To test the accuracy of human-generated wind gust reports, the researchers compared Storm Data wind speed entries from storm reporters who didn't use anemometers with wind data from automated weather stations. In the study, which appeared online on 19 April, the authors also used instrumental data from the Global Historical Climatology Network as a comparison for the human-reported gusts.

The researchers focused on windstorms without rain, lightning, or other phenomena that could frighten observers, accidentally inflating their estimates of the storm's intensity. They also eliminated news media reports from consideration as human observer data, because news reporters might have relied upon instrumental data from local weather stations.

Even with those potential biases removed, the comparisons revealed that storm reporters overestimated the speeds of wind gusts—on average, by about one third of the gusts' actual speeds.

These inflated estimates could have introduced inaccuracies into any study that relied on Storm Data for climatological or storm modeling information, Miller said.

Overestimation: Consequences and Cures

Inflated estimates can have real consequences for society. If people hear that winds are stronger than they actually are, they may alter their behavior—for example, evacuating their homes unnecessarily during a hurricane.

That leads to another sort of trouble. "People who choose to evacuate eat up resources for people who truly need to evacuate," said Gregory Webster, a psychologist at the University of Florida in Gainesville, who was not involved with the study. "It causes extra traffic congestion, and can sometimes result in even more severe food hoarding" when frightened residents buy out all the water and nonperishable food they can find, leaving less for those who might truly need it.

Fixing the problem may prove difficult, said Miller. Many different factors contribute to overestimations—for instance, outdated storm reporter training, he noted.

Storm reporters learn, in training, to use the Beaufort Wind Force Scale, which relies on environmental cues to determine how fast the wind is blowing. According to Miller, the Beaufort Scale is flawed. As an example, the scale indicates that trees blow over at wind speeds of 58 miles per hour and above. However, Miller said his research shows that trees can fall over at much lower speeds, in the low 40-mph range.

"Wind speeds are hard to estimate, especially when you're talking about trees," said Storm Data's MacAloney. "We're meteorologists, not arborists."

The value of Storm Data lies in its scope, which includes remote areas without on-the-ground weather stations, MacAloney maintained. Despite their potential biases, human reports from such locations provide vital information such as narratives about highly localized events—for example, tornadoes and hail—that weather stations miss.

The authors of the new study agree, saying that Storm Data remains a valuable resource but needs a better system for flagging wind reports generated from people's observations alone.

By **Elizabeth Deatrick,** Editorial Intern

Richard P. Von Herzen (1930–2016)


Special Collections & Archives, UCSD Library

Richard P. Von Herzen

Richard P. Von Herzen, 1998 Maurice Ewing medalist, AGU Fellow, and world-renowned geothermal scientist, passed away peacefully on 28 January 2016 at the age of 85. Dick had an incredibly positive influence on the careers of many marine geothermal scientists throughout the world. On behalf of his many colleagues and friends who feel the loss deeply like we do, we wish to commemorate the many accomplishments of his distinguished career.

Dick earned his B.S. in geophysics at the California Institute of Technology in 1952, and after a tour of duty in the U.S. Army, earned his M.A. in geology at Harvard in 1956 and a Ph.D. at the Scripps Institution of Oceanography in 1960. He remained at Scripps for 4 more years as a research geophysicist, then moved on to a 2-year stint as deputy director of the United Nations Educational, Scientific and Cultural Organization's Office of Oceanography in Paris.

In 1966 he took a research scientist position at the Woods Hole Oceanographic Institution (WHOI), his professional base for the next 50 years. During the course of his career, Dick made many fundamental scientific contributions in marine geothermal research and also was a leading developer of the instrumentation needed for making geothermal measurements at sea. As Seiya Uyeda said so well in his citation when Dick was awarded AGU's Maurice Ewing Medal in 1998, "Dick has virtually established marine heat flow as a discipline within marine geophysics."

Dick was rigorous in his science and measurement techniques and was known throughout the community as a consummate, modest gentleman who thrived on collaboration and graciously mentored young scientists from WHOI and other institutions.

Early Studies of Seafloor Spreading

Dick led many of the seminal seafloor geothermal studies completed during the exciting 1960s–1970s period, when plate tectonics was being developed and accepted as a theory and also when hydrothermal circulation was discovered in young oceanic crust.

Dick's letter to *Nature* [*Von Herzen,* 1959] and *Journal of Geophysical Research* paper with Seiya Uyeda on heat flow in the eastern Pacific [*Von Herzen and Uyeda,* 1963] first documented high values centered along the bathymetric rise that we now know as the East Pacific Rise spreading center. Dick and Seiya attributed this to "large-scale thermal convection in the mantle," and these measurements provided important supporting evidence for the emerging concept of seafloor spreading.

Five years later, Dick was co–chief scientist with Art Maxwell on Deep Sea Drilling Project (DSDP) Leg 3, which famously validated seafloor spreading by dating the basal sediments on a transect of sites across the South Atlantic [*Maxwell et al.,* 1970].

Pioneering Work on Hydrothermal Circulation

In the early 1970s, Dick and his student Dave Williams collected bottom water temperature profiles across the Galapagos Rise that provided the first evidence for the existence of hydrothermal plumes rising from spreading centers [*Williams et al.,* 1974]. Their spatial profiles of seafloor heat flow across the Galapagos Rise showed a regular variation with distance from the axis, which they interpreted as a result of cellular hydrothermal circulation within the oceanic crust, as had just been hypothesized by the University of Washington's Clive Lister [*Lister,* 1972].

Following up in 1977, Dick was coleader of the submersible expedition that returned to the Galapagos Rise and first discovered hydrothermal vents on the seafloor (relatively low temperature vents in this case) and their unique ecosystems (see http://bit.ly/1ZbZgVB).

In his fieldwork during the following decades, Dick continued to document hydrothermal circulation in young ridge flanks near a number of spreading centers, as well as the persistence of hydrothermal circulation in surprisingly old oceanic crust [*Fisher and Von Herzen,* 2005]. With a number of coinvestigators, he also conducted several heat flow surveys to investigate geothermal processes associated with oceanic hot spots and swells, notably the Hawaiian Swell, the Bermuda Rise, and the Reunion hot spot track. In addition, he was one of the earliest to interpret sediment temperature profiles for evidence of recent changes in bottom water temperatures related to climate change [*Fisher et al.,* 1999].

Contributions in Heat Flow Instrumentation

In support of his geothermal fieldwork, Dick pioneered many instrumental developments that set standards still in use in the marine sciences. These were not necessarily hugely innovative in a technological sense, but he had a true talent for packaging equipment to make relatively straightforward measurements (e.g., temperature) rigorously and reliably under challenging deployment conditions.

His contributions in this vein included the following:

- with Art Maxwell, the needle-probe method to determine the thermal conductivity of marine sediments [*Von Herzen and Maxwell,* 1959]
- some of the earliest digital heat flow data loggers (which had also been developed independently by Clive Lister)
- multipenetration "pogo probe" heat flow instrumentation with real-time acoustic telemetry of data during measurements
- the short heat flow probes used by the U.S. research submersibles *Alvin* and *Jason* [*Becker et al.,* 1996]
- downhole probes to determine sediment temperatures during Project Mohole and in DSDP boreholes, including miniaturized temperature recorders inside the cutting shoes of the hydraulic piston corer as still used in scientific ocean drilling [*Horai and Von Herzen,* 1985]

Personal and Collegial Accomplishments

Dick was the great-great-grandson of the famous 19th-century Russian novelist and political writer Alexander Herzen. He was an

excellent athlete; during his military service he swam the breaststroke leg for the gold medal U.S. Army relay team.

Dick and his beloved wife, Jan, were gracious hosts to many scientists who visited WHOI, as fondly remembered by both of us. Dick and Jan are survived by their two accomplished children, Brian and Lane; Brian's life partner, Rebecca Truman; Lane's husband, Ken MacWilliams; and two grandsons, Graham and Duncan MacWilliams.

One of Dick's most enduring legacies is the positive and supportive influence he had on the careers of many younger geothermal scientists, some of whom honored his contributions in a February 1983 special section of *Journal of Geophysical Research: Solid Earth* ("Honoring Richard P. Von Herzen," *88*(B2), 993–1104, 1983).

Dick's rigorous attention to detail set a standard for all of us involved in heat flow measurements at sea. At the same time, his thoughtful and generous demeanor set a standard for collegial interactions. Dick exemplified the best traits of a mentor long before effective mentoring was identified as an academic expectation.

Those of us who were lucky enough to know and work with Dick deeply valued his friendship as well as his professional collaborations. We will miss him sorely, and we will remember and honor him as a visionary leader and one of our most influential colleagues.

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Climate Predictions and Infectious Diseases in Southern Africa

Symposium for Science and Technology Research Partnership for Sustainable Development (SATREPS) Project 2015
Pretoria, South Africa, 12 October 2015

Jim Gathany/CDC

An Anopheles gambiae *mosquito, the primary mosquito vector responsible for transmitting malaria in most of sub-Saharan Africa, sucks the blood of a human.*

Infectious diseases are one of the leading causes of death in today's changing world. Their impact is especially severe for developing and newly industrialized countries, including those in sub-Saharan Africa. According to a World Health Organization report (http://bit.ly/WHO-Malaria), in 2013, 90% of the approximately 630,000 deaths worldwide from malaria occurred in this region. Most of these cases involved children younger than 5 years old.

Because of the effects of malaria and other diseases, including cholera and pneumonia, a child born in sub-Saharan Africa is 15 times more likely to die by the age of 5 than is a child in a developed country. However, the earlier that disease outbreak warnings are released, the more quickly action can be taken to prepare for the potential impact on a population.

The Science and Technology Research Partnership for Sustainable Development (SATREPS; http://bit.ly/SATREPS), a program funded by the Japan Agency for Medical Research and Development and the Japan International Cooperation Agency, promotes international research partnerships and collaboration between developing countries and Japan. Our project, Establishment of an Early-warning System for Infectious Diseases in Southern Africa Incorporating Climate Predictions (http://bit.ly/Early-Warning), was initiated in 2014 following the successful completion of another SATREPS project on the southern African climate.

> The current project focuses on creating a disease outbreak early warning system over southern Africa.

The current project focuses on creating a disease outbreak early warning system over southern Africa that can be implemented effectively to fight infectious diseases. It also includes a training component for young researchers and students in South Africa.

As a part of this project, researchers from South Africa and Japan gathered in Pretoria, South Africa, to hold a symposium discussing recent findings and ways to interact with the country's emerging researchers. Participants included members of research institutes from South Africa and Japan and comprised specialists in multidisciplinary fields, as well as local graduate students who have interests in climate modeling and infectious diseases. The symposium covered four topics:

- malaria and vector ecology
- cholera and pneumonia research
- disease transmission models
- climate prediction systems

Participants reported recent findings in their respective subprojects. For example, the South African Medical Research Council conducted laboratory experiments in Limpopo in an attempt to discover the entomological parameters of anopheline mosquitoes, the vector species responsible for the transmission of malaria between humans.

Another focus was on the collation of handwritten hospital admissions records for malaria, cholera, and pneumonia cases, emphasizing the need for collection of good quality data. These data serve as the input for sophisticated statistical studies, which use techniques including machine learning and Bayesian modeling. The data are essential for developing global climate models in relation to disease transmission that depend on the epidemiological characteristics of the diseases.

As a result of this meeting, a lecture series was held at the University of Limpopo to teach students about weather and climate variability, climate change, disease vector ecology, and statistical methods, as well as the relationship between climate and health and epidemiology. Students interacted with the lecturers, engaged in the course material, and experienced a stimulating environment that deepened their understanding.

Although there will be challenges ahead, the achievements thus far have taken the project a significant step toward developing an early warning system for infectious diseases in southern Africa.

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The Broken Bridge Between Geology and Museums

The bridge between the museum community and the Earth science education and research communities has fallen into disrepair. Tight budgets limit the efforts of Earth science curators to create compelling displays and education programs for the public, and irreplaceable collections of rocks and minerals are in danger of being sold off or discarded. Rebuilding the connections has important benefits for everyone concerned.

In the past, mineral museums played an important role in documenting, preserving, and promoting geological diversity. For example, my employer, the North Carolina State Museum (now the North Carolina Museum of Natural Sciences), was founded in 1879 to attract attention to natural resources and to rebuild a crippled economy in the wake of the American Civil War. The state geologist's collection served as the nucleus of the exhibits, which traveled as far as Paris, New Orleans, and the 1906 Centennial Exposition in St. Louis, Mo.

Museum collections are also an important source of research specimens: I have used mineral specimens from the Mineralogical and Geological Museum at Harvard University and the Smithsonian Institution in my own research. Collections are official repositories for type specimens for minerals and meteorites.

A third function of museum mineral collections is to educate visiting students, from K–12 up to the university level. Mineral exhibits benefit local economies by attracting tourists and mineral enthusiasts, who also gain an educational benefit.

Museums can't perform these functions unless their mineral and rock collections are adequately funded and maintained. Geological collections have not had access to the types of funding typically available to other disciplines. For instance, the biological sciences recognize the value of long-term specimen storage, and money is available to support that. Some biology grants are even open to paleontology collections.

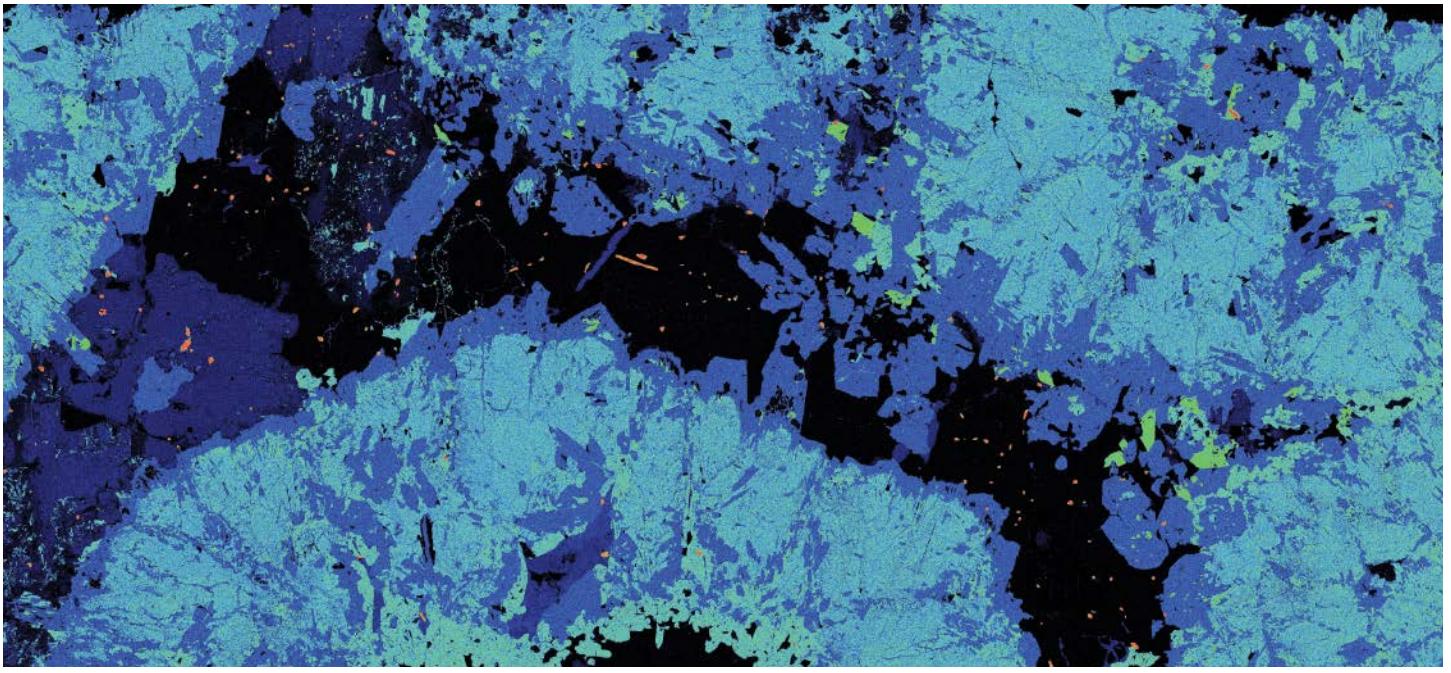
Even biological collections are not immune to funding cuts, however. This March, the National Science Foundation announced that it was not accepting new grant proposals for its Collections in Support of Biological Research program, which has been suspended indefinitely. An opinion piece on the nation's beleaguered natural history museums and their collections ran in the Sunday Review section of the *New York Times* in early April (see http://nyti.ms/1sINU0D). Geological curators can sympathize with the plight of the biological collections, but rock and mineral collections have been coping with this lack of funding as a matter of course for many years.

History for Sale

The urgency in supporting museum collections is predicated on an essential difference between geoscience collections and biological collections. Geology collections are *worth money*. Even the ugliest rock is "pedigreed" in a collector's eyes. The parts of biological collections that could be monetized are species covered by the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which forbids trade in endangered species. Paleontology collections have some monetary value, but the big money generally lies in sales of carnivorous dinosaur bones. However, Bureau of Land Management policy forbids sale of fossils found on public lands (see http://on.doi.gov/20RsCcj).

In contrast, administrators looking to monetize collections can get rid of a geology collection, free up space and budget, and earn extra money doing it. The Philadelphia Academy of Natural Sciences (now the Academy of Natural Sciences of Drexel University) took this step in 2006. Without external funding for collections support, I expect it will become more common in the future.

This issue took on a disturbing urgency for me when I found item 143B-135.233 in the 2015



Christopher Tacker

X-ray map, using calcium Ka radiation, of orbicular (disk-shaped) diorite from Davie County, North Carolina. The only outcrop is now heavily weathered, but specimens at the Museum of Natural Sciences were mined in 1903. Field of view is slightly less than 27 × 46 millimeters.

North Carolina State Budget. This item specifically authorized the museum to sell or trade anything from its collections "when it is in the best interests of the Museum to do so."

Scrambling for Public Funds

My role as geology research curator is to curate a unique natural resource used to generate new knowledge and understanding. The Geology Collection is a research collection, although we support exhibits as well. Our collection focuses on North Carolina's geodiversity and, to a lesser extent, that of the southeastern United States. It contains many significant North Carolina specimens, most from sites that are now inaccessible. Many gold mines are now flooded, road cuts have been landscaped, and urbanization has erased mines and outcrops alike. According to an account from one of my colleagues, the type locality for websterite, in Webster, N.C., has been dynamited and sold.

This collection serves as a seldomly used archive for the specimens collected by retiring professors, and we are tasked to preserve their life's work *in perpetuity*. Support from the state of North Carolina is minimal, and we receive no funds for developing the collection, improving storage cases, or generating modern-day characterizations of specimens. We receive no financial support from any other sources.

Grant money is available from the National Geological and Geophysical Data Preservation Program, but these funds are offered exclusively to state geological surveys through the U.S. Geological Survey. Other grants apply only to the large repositories. Smaller collections and museum-based repositories have no access to these sources of funding.

The worst, and most flagrant, example of exclusion is the often-cited 2002 National Research Council report *Geoscience Data and Collections: Natural Resources in Peril* (http://bit.ly/NRC-Geoscience). A committee made up of paleontologists and petroleum exploration geologists generated the report, with no geology museum professionals included. Accordingly, museum-based mineralogy/petrology collections rated a total of two paragraphs in the entire 101-page report. Funding followed proportionally.

The only program on the horizon is National Science Foundation (NSF)-funded EarthCube, which focuses on creating digital infrastructure. If one digs deeply enough into the EarthCube-funded iSamples Research Coordination Network, one can find mention of museums and actual physical samples. EarthCube represents a bonanza for computer professionals but little or nothing for medium-sized museum collections where collection numbers are actually put on rocks. We need money for cases, database upgrades, trained assistants, thin sections, and analytical instrument time for validating mineral identification. We need money to address the special needs of curating radioactive minerals, asbestiform minerals, and sulfide minerals. But the money is going to digitization, so any funding for the long-neglected collections looks to be too little and too late.

Christopher Tacker

Polished slab of orbicular diorite from Davie County, North Carolina, prior to thin sectioning. The orbicules are amphibole in a plagioclase and potassium feldspar matrix.

Missed Opportunities

If we look at the bridge from the other end, we can ask, What do museums do to advance the profession of geology? Museums are the open entrance to the pipeline, where children can begin to dream about a career. It could be so for the geosciences too, but mineral museum exhibit design stagnated in the 18th century with the "cabinet of specimens." Geology exhibits are generally limited to cases crammed full of minerals. Explanatory text is limited to a card with the mineral name and, sometimes, a chemical formula. This exhibit style has little value, educational or inspirational. A visitor can walk away from a case full of meteorites with the message that the museum owns a lot of little black rocks with funny names.

Few exhibits highlight the huge amounts of information represented by the minerals or the (nearly magical) ways in which we get that information by microanalysis and experiment. Recent findings in cosmochemistry, seismology, deep-sea drilling, volcanology, the deep Earth, and climate change are nearly totally absent.

Geoscientists own the best stories in all of the sciences, but these stories have all been appropriated by other sciences. Would we understand the depth and breadth of global warming as fully without stratigraphy, micropaleontology, and stable isotopes? Would organic evolution be as firmly established as the basis of biology without the proof that comes from the geosciences?

Museums and curators must follow the money, much of which comes from wealthy collectors. So mineral museum professionals gather at Tucson or Denver gem and mineral shows rather than AGU or Geological Society of America meetings. The NSF Division of Earth Sciences does not fund the development of exhibits as a means of outreach. Informal science education grants allow exhibit design and development but only as one of a myriad of eligible formats. We are left with static mineral exhibits, which are cheap to build and maintain and are preferred by collectors. These fail to hold the interest of the casual visitors or of tech-savvy youth.

Looking Ahead

The research and academic communities should rethink their support of museums as repositories and archives. When a researcher retires and his or her samples end up in the dumpster, research is squandered. Funding a few major repositories may create an archive, but repositories lack the outreach and built-in audience a museum commands. Repositories completely lack an exhibits staff of professional writers, artists, and fabricators dedicated to reaching an audience.

The National Science Foundation is the principal support for the Earth sciences and is responsive to the needs of the community. Changes that extend funding to museum collections and outreach (from a finite budget) can be accomplished with the support of the community, within and outside of NSF.

The future of the Earth sciences depends on reestablishing mutually beneficial relations, rebuilding the bridge, between Earth scientists and Earth science museums. Museums need Earth science community support for funding for collections, exhibits, and programs that go beyond dinosaurs or ultraviolet fluorescent minerals. Museums must better support the scientists as direct outlets for information. Museums and geoscientists both need the next generation of geoscientists, who could discover *all* the wonders of geology at their local museum.

This essay represents the opinion of the writer, not the Museum of Natural Sciences, the Department of Cultural and Natural Resources, or the state of North Carolina.

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What Does the Pacific Arctic's **New Normal** Mean for Marine Life?

By Lisa Sheffield Guy, Sue E. Moore, and Phyllis J. Stabeno

Climate change has reconfigured Arctic ecosystems. A 5-year project focuses on the relationships among oceanographic conditions and the animals and other life-forms in this region.

Recent changes in global climate patterns have redefined what "normal" weather looks like. A "new normal" Arctic has a longer open-water period in summer and wider extremes of weather variability overall.

Before 2010, for example, sea ice covered more than half of the Beaufort and Chukchi seas year-round. Now these seas have less than 50% sea ice cover, and only for an average of 67 days per year [*Wood et al.*, 2015]. Tem-

Phil Gould/Alamy Stock Photo

A killer whale's tail. As climate changes, shifts in the marine food web may bring killer whales and other species to the Pacific Arctic.

perature and wind drive changes in sea ice, but the effects are variable across the Pacific Arctic [*Frey et al.*, 2015].

In an effort to provide an interdisciplinary look at completed and ongoing marine research on the Pacific Arctic, a cross-institutional group of researchers launched the Synthesis of Arctic Research (SOAR) in 2011. SOAR delves into the emerging effects of the new normal on Pacific Arctic marine life.

An Interdisciplinary Synthesis

Specifically, SOAR aims to increase scientific understanding of the relationships among such oceanographic conditions as physics, chemistry, and sea ice; benthic (seafloor) organisms; and species occupying various trophic levels (the position an organism occupies in the food web) in this region.

This 5-year effort began with a 3-day workshop to identify science themes and relevant data sets and to form synthesis teams to address high-priority questions about the new normal Pacific Arctic [*Sheffield Guy et al.,* 2012]. More than 100 Arctic scientists and local experts completed the first phase of this effort, an interdisciplinary synthesis of marine ecosystem science in the Pacific Arctic, in August 2015.

The synthesis strengthens scientific understanding of recent, extreme changes in the region's biophysics, such as sea ice loss and change in occurrence of high-latitude species. It was structured around three themes. The first is observations and models of sea ice loss and effects on primary production—the ability of organisms at the base of the food web to synthesize organic compounds from carbon dioxide. The second is the response of middle trophic species, such as forage fishes, to the new state of the Arctic. Rounding out the synthesis is the third theme: responses of top-level predators—seabirds, seals, walruses, and whales [*Moore and Stabeno,* 2015].

What Does the New Normal Pacific Arctic Look Like?

In the future, the Arctic will be a different place than it was even a few decades ago. Alaskan Arctic winters are expected to remain seasonally icy, but the duration of the summer open-water period will continue to lengthen [*Wang and Overland,* 2015]. Fewer days of sea ice cover and reduced sea ice thickness and extent increase the phytoplankton growing season: Net primary production has increased dramatically, by 30% since the late 1990s across the Arctic Ocean [*Arrigo and van Dijken,* 2015].

Ocean acidification is also increasing. This will affect commercial and subsistence fisheries because the lower pH

A Pacific loon swims in a lagoon near Barrow, Alaska.

Bill Schmoker (PolarTREC 2010)/ARCUS

makes it difficult for marine organisms to grow and maintain hard shells and skeletons [*Mathis et al.*, 2015].

How Does the New Normal Affect Specific Species?

Middle trophic-level marine communities, including benthic organisms and key forage fishes, have variable responses to the new normal conditions. Benthic "hot spots" identified by high biodiversity and biomass have been tracked over the past 3 decades, with some showing a northward trend in their epicenters [*Grebmeier et al.*, 2015]. Ripple effects from this northward shift extend to all levels of the food web, helping some species and challenging others.

For example, nearshore patches of benthic prey (clams, polychaete worms, crabs) dense enough to be profitable for such predators as eiders change both spatially and annually, making it difficult to pinpoint key foraging areas to protect [*Lovvorn et al.*, 2015]. Chinook salmon (*Oncorhynchus tshawytscha*) may be moving northward into the Arctic as conditions become more favorable [*Logerwell et al.*, 2015]. Some populations of ringed and bearded seals (*Phoca hispida* and *Erignathus barbatus*, respectively) are growing larger, and their blubber is thicker [*Crawford et al.*, 2015].

Some commercially important fish in the cod family are present in the Arctic but don't appear to be spawning [*Logerwell et al.*, 2015]. As Arctic cod (*Boreogadus saida*) follow the receding ice edge, they are moving out of foraging range for an Arctic seabird, the black guillemot (*Cepphus grylle*), that feeds on them. Black guillemot parents struggle to feed their nestlings, whose health has declined [*Divoky et al.*, 2015]. Average weight of guillemot chicks declined by 25 grams in the new normal (2003–2012) when compared with a historical period (1975–1984).

Top predators (including seabirds, walrus, and whales) are also responding to changing biophysical conditions in the new normal Pacific Arctic. SOAR participants identified seabird and marine mammal hot spots throughout the Pacific Arctic. Seabird and marine mammal hot spots overlapped at the mouth of Barrow Canyon, a submarine canyon off the northern coast of Alaska [*Kuletz et al.*, 2015].

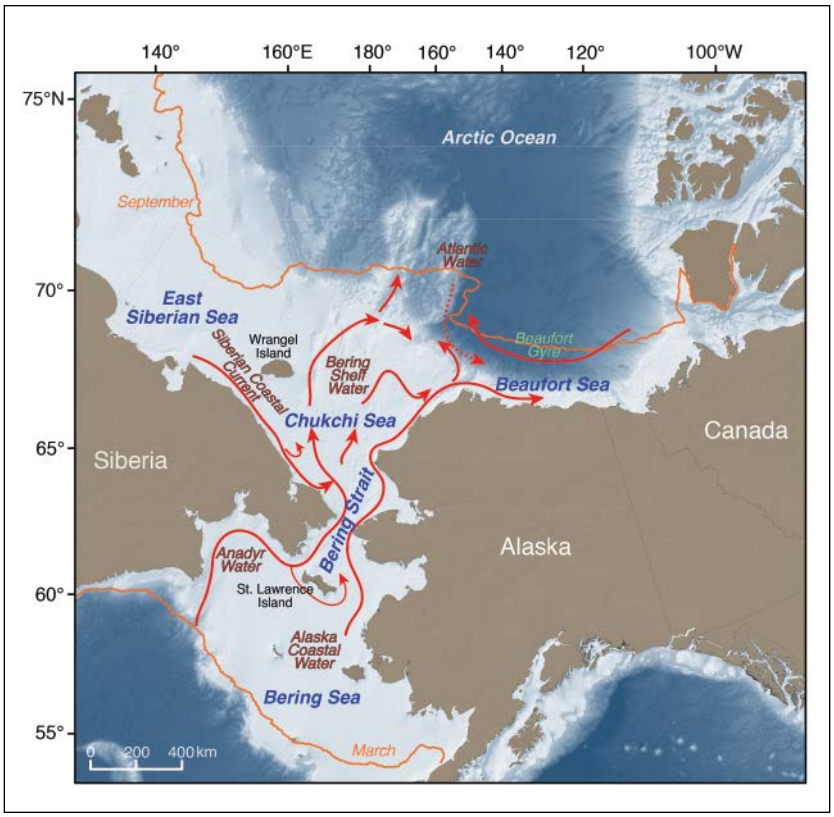
Project participants defined core-use areas, where bowhead whales regularly concentrated, in the Bering-Beaufort-Chukchi seas [*Citta et al.*, 2015]. For the first time, data from acoustic recorders throughout the region were combined to describe the acoustic world encountered by bowheads throughout their annual migration [*Clark et al.*, 2015]. This SOAR study captured recordings of bowheads and bearded seals singing over periods lasting more than a month, the sounds of seismic air guns and high winds, and, of course, quiet periods.

Alaskan Arctic winters are expected to remain icy, but the duration of the summer open-water period will continue to lengthen.

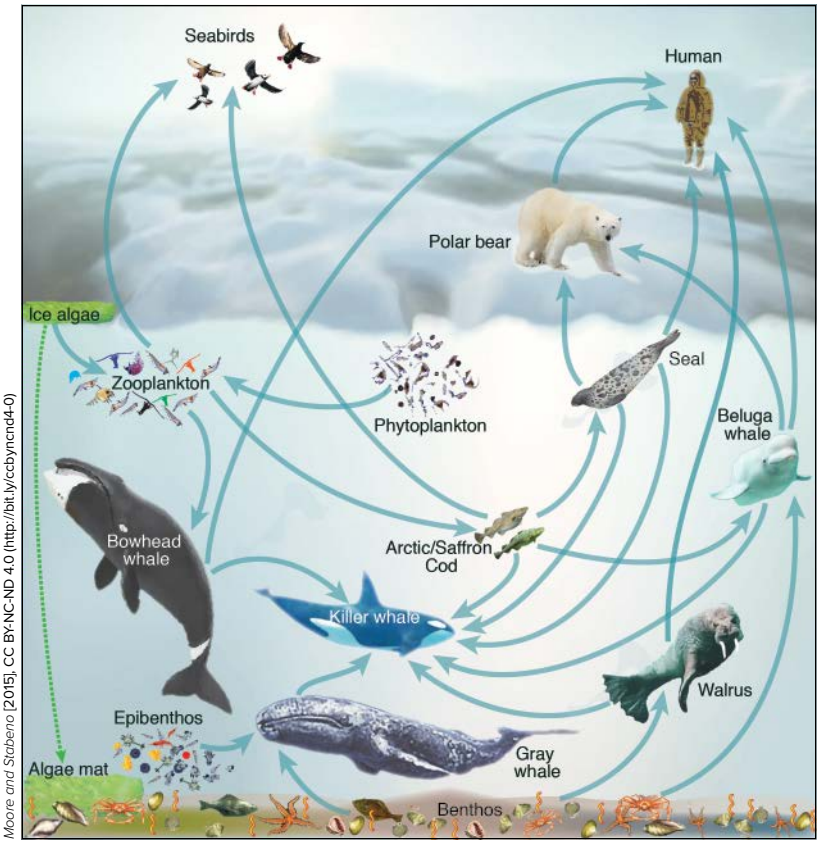
Bearded seals vocalized more frequently in areas with more sea ice and during the mating season. Thus, sea ice loss may negatively affect the behavioral ecology of this species [*MacIntyre et al.*, 2015]. Growth and body condition (an indicator of overall health based on measures of body fat, size, and age) for such other species as ringed seals and belugas have also suffered [*Harwood et al.*, 2015]. In contrast, bowhead whale body condition has improved approximately 2.7% per decade since 1989, coincident with sea ice loss, likely due to more favorable conditions for the whales' zooplankton prey [*George et al.*, 2015].

Beyond the New Normal

Changes in marine bird and mammal habitats and health reflect changes in the ecosystem as a whole. We can look to



Pacific Arctic region with maximum (March) and minimum (September) sea ice extent and major currents (red arrows).



Moore and Stabeno [2015], CC BY-NC-ND 4.0 (http://bit.ly/ccbyncnd4-0)

Schematic marine food web for the Pacific Arctic.

top predators as sentinels of this change. For example, a shift from a Pacific Arctic driven by benthic production on the ocean's floor to one dominated by burgeoning pelagic life near the surface is reflected in the abundance and health of these animals. This shift will also attract new species, such as killer whales (*Orcinus orca*), not historically observed in the region.

Monitoring and predicting conditions in the Pacific Arctic are therefore top priorities. To these ends, a SOAR contribution by *Moore and Stabeno* [2015] introduced the Arctic Marine Pulses (AMP) conceptual model, which depicts seasonal "pulses" of nutrients, zooplankton, and forage fishes transported from the northern Bering Sea through the Bering Strait, across the Chukchi Sea, and into the Beaufort Sea. SOAR participants plan to further refine the AMP model by investigating variability in atmospheric forcing of inflow at Bering Strait and summarizing currently known changes to pelagic-benthic coupling, transport, and nutrient upwelling events in the Chukchi and Beaufort seas.

A shift from a Pacific Arctic driven by benthic production to one dominated by burgeoning pelagic life will attract new species, such as killer whales.

The second and final phase of SOAR will extend the synthesis effort and culminate in a new special issue of the journal *Deep-Sea Research Part II: Topical Studies in Oceanography*. Papers for the issue are currently in review, with a total of 16 contributed articles expected. Complete lists of SOAR Phase II special issue papers, contributors, and associated products are available online at http://1.usa.gov/21qJQos.

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A bearded seal rests on shorefast ice over the Beaufort Sea.

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Does Geothermal Exploitation Trigger Earthquakes in Tuscany?

By Thomas Braun, Torsten Dahm, Frank Krüger, and Matthias Ohrnberger

Mount Amiata in the pre-dawn light, with the landscape of Tuscany below.

Robert Garrigus/Alamy Stock Photo

How hot is an extinct volcano? It depends on how deep you look. A magmatic dike of 1-meter thickness intruding near Earth's surface will solidify within a few weeks. A thick magmatic reservoir formed at mid-crustal level will need a much longer time to solidify, and the resulting heat anomaly can be present for some hundred thousand years.

Such long-lasting, natural reservoirs of heat represent a perfect energy source for geothermal exploitation: Water injected into the ground reaches the still-hot core of the volcano, where it heats up and produces steam. Depending on temperatures, the heated water can be used to produce electric energy, either directly—the steam then drives turbines—or by heat exchange with a fluid having a lower evaporation point.

The picturesque landscape of Tuscany, Italy, is home to such an extinct volcano: Mount Amiata. Scientists estimate that the volcano's last period of eruptive activity occurred about 200,000 years ago. Still characterized by a high geothermal gradient, the area lends itself to steam-dominated geothermal exploitation.

After nearly a century of generating geothermal power, energy extraction in Tuscany might be entering a new phase. For the past 25 years, production has been accompanied by a small but steady increase in seismicity near geothermal wells. Tuscan communities are beginning to wonder: Does generating power trigger this seismicity? A new project seeks answers.

Tuscan Geothermal Fields

Beneath the Tuscan geothermal fields, seismicity is exclusively observed in the upper crust and is confined at depth by the so-called K horizon, a strong seismic reflector revealed by intensive exploration and prospecting. The horizon is interpreted as a surface representing temperatures that reach 400°C. Below this, the crust becomes more ductile and less prone to seismic events.

The K horizon is observed in the Tuscan geothermal fields at depths as small as 4500 meters [*Batini et al.,* 2003]. Structures above this horizon contain permeable layers of highly fractured, volcanic rocks. Rainfall draining through these layers heats up, saturating the rocks with hot water and steam.

Because hot areas are so close to the surface, communities dating back to Roman times harnessed the hot springs as therapeutic baths. In 1904, gentleman scientist Prince Piero Ginori Conti tested the world's first geothermal power generator—successfully lighting five lightbulbs—in Tuscany's Larderello district. In 1911, Larderello became home to the world's first commercial geothermal power plant. In fact, until 1958, Tuscany was the only area in the world producing geothermal energy.

More plants were built in volcanic areas of Tuscany and Latium in the 1960s, including several near Mount Amiata and Latera, and production across the Tuscan geothermal fields has continuously increased ever since. Today geothermal energy from Tuscany accounts for 1.5% and 23.5% of energy produced in Italy and Tuscany, respectively, and 8% of geothermal energy produced around the world.

Geothermal Field of Mount Amiata

Scientists consider shallow intrusive magma bodies to be the heat sources of two of Tuscany's most important geothermal areas, Larderello and Mount Amiata. However, the two areas do have their differences: In the Larderello area the magma ascent became stuck in the upper crust; in the Mount Amiata area, magma reached higher into superficial layers, and the eruptive activity formed a volcanic edifice, reaching an altitude of 1738 meters [*Gianelli et al.*, 1997].

Geothermal exploitation at Mount Amiata volcano started in 1959, through wells reaching initial depths of less than 1000 meters. Because the geothermal temperatures rise 15°C each hundred meters or so, such relatively shallow drilling depths were sufficient for the extraction of vapor and reinjection of cold water, using the natural fracture system of the rock volume for the circulation of the fluids.

Nowadays the geothermal energy company Enel Green Power runs two power plants of 60 megawatts each, Piancastagnaio and Bagnore, located in the southeast and southwest parts, respectively, of Mount Amiata (Figure 1). Both plants harness hydrothermal systems, meaning that energy production requires no pressurized fluid injection to enhance the permeability of fluid pathways, because the upper crust there is highly permeable. Reinjected fluids simply sink by gravity.

Seismic Activity of Mount Amiata

Compared to other Italian areas, the recorded seismic activity at and around Mount Amiata is generally very low. The Italian Seismological Instrumental and Parametric Database reports no more than 140 seismic events with a magnitude greater than or equal to 1.5 for the past 25 years (Figure 1). This may be caused, in part, by the limited detection capabilities of the sparse regional Istituto Nazionale di Geofisica e Vulcanologia (INGV) seismic network (MCIV in Figure 1); however, the high heat flow and the consequential ductile behavior of the upper crust may be the reasons for this low seismic activity. How much seismicity an extinct but still hot volcano generates is up for debate.

The geothermal power plant of Bagnore situated at the foot of Mount Amiata and run by Enel Green Power, the Italian multinational manufacturer and distributor of electricity.

Thomas Braun

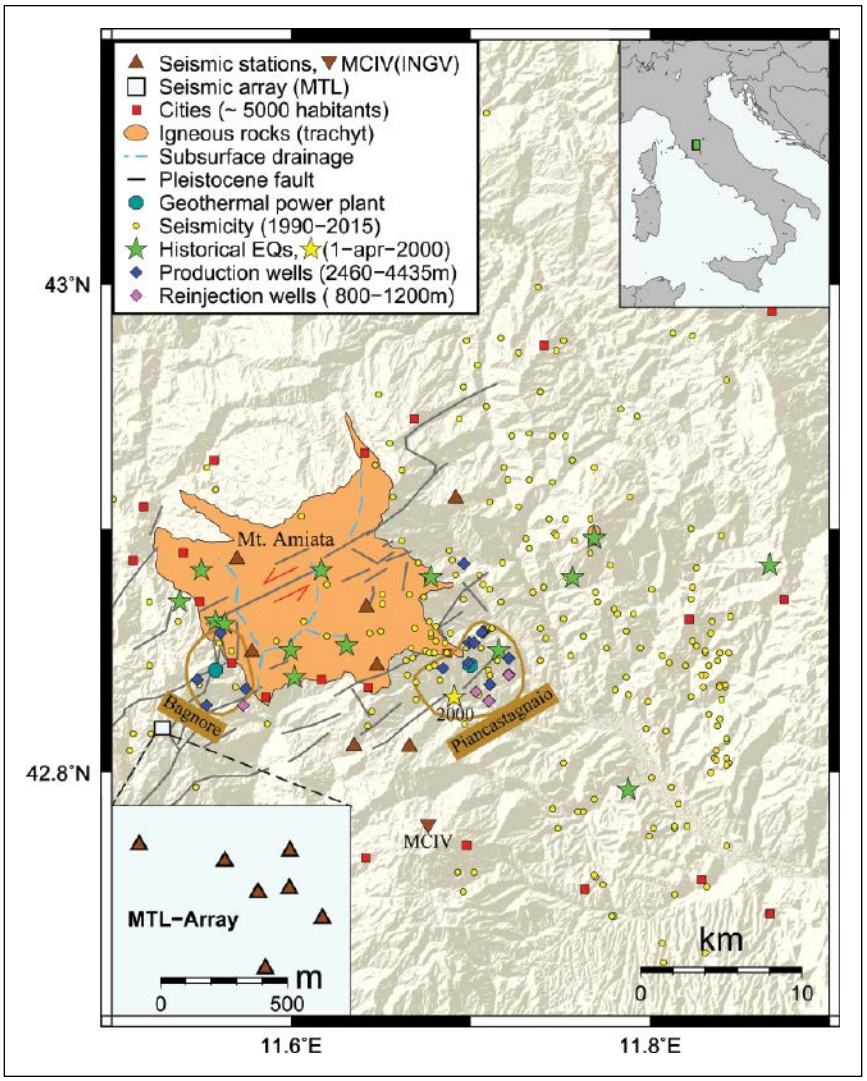

Fig. 1. Map of Mount Amiata with main faults, historical earthquakes (green stars), and seismicity recorded by the Istituto Nazionale di Geofisica e Vulcanologia (INGV) network during the past 25 years (yellow dots). Gold-ringed areas are the geothermal areas of Bagnore and Piancastagnaio with their respective power plants (octagons). Blue dashes denote the subterranean drainage paths on the prevolcanic paleomorphology. Brown triangles represent the seismic network, and the close-up shows the seismic array configuration of our experiment. The inset map shows the location of the study site within Italy.

Damaging earthquakes struck the geothermal fields in south Tuscany long before geothermal exploitation started. The Parametric Catalog of Italian Earthquakes reports 13 moderate seismic events $4.5 \leq M_e \leq 5.3$ between 1287 and 1940 on the basis of inferences of observed effects of historic earthquakes using the Modified Mercalli Intensity Scale [*Rovida et al.*, 2011].

In recent times, an earthquake on 1 April 2000 has raised the strongest concern among the general public for several reasons. First, its very shallow hypocentral depth was responsible for damaging more than 50 buildings at Piancastagnaio. Also, the proximate location of the geothermal power plant with respect to the macroseismic epicenter raised strong doubts about the natural origin of this earthquake.

In addition, reports of different magnitudes, ranging from local magnitude (M_L) = 3.9 to moment magnitude (M_w) = 4.5, were presented without context [*Castello et al.*, 2006; *Rovida et al.*, 2011]. Local magnitudes are felt in proximity to the epicenter, whereas moment magnitudes incorporate low-frequency seismic information to reflect the broader area ruptured. The use of both values caused confusion and did not help to mitigate the population's distrust of the institutions reporting on the earthquake.

Because the earthquake's hypocenter was located near the geothermal power plant, at a depth (~4 kilometers) similar to the geothermal well depth, it was difficult to determine whether the earthquake source was natural or anthropogenic. Thus our seismic network was developed to shed some additional light on what triggers earthquakes in this area.

Geothermal Reservoir

Mazzoldi et al. [2015] report that pressure has continuously decreased over several decades inside the upper geothermal reservoir. This decrease led the power company Enel to deepen the production in the 1980s into a second reservoir, located at a depth of 2500–3500 meters. Continuous exploitation reduced the fluid pressure at these depths from 25 megapascals to less than 10 megapascals.

This strong pressure drop inside the geothermal reservoir could lead to the vaporization of originally water-dominated fluid. Vaporization and reinjection with cold water may lead to thermal stressing of rocks. In addition, depletion of fluid from the reservoir may also induce elastic stresses in surrounding rock [*Dahm et al.*, 2015].

These mechanisms may lead to both stabilizing and destabilizing effects on faults. For example, decreasing pore pressure on a fault is usually assumed to stabilize, or lock, the fault. The elastic bending of geological layers has been discussed as a mechanism to trigger earthquakes.

Public Concerns

Following the nuclear accident in Fukushima, Japan, caused by an M_w = 9.0 earthquake in 2011, Italy—which

has no active nuclear plants—shut down by a national referendum all future plans for nuclear power plants. This raised a gold rush–like interest in domestic alternative energy production—solar, eolian, and geothermal, the latter motivated by the favorable geological conditions in central Italy.

Despite the general environmental sustainability of geothermal energy, major criticism from local citizens' action committees concerns possible contamination of the groundwater by dissolution of mercury and the possibility of triggering earthquakes due to changes in thermal stresses and strong pressure drop as a consequence of the continuous energy production. Our project aims exclusively at the latter point.

A Seismic Network

To monitor the seismic activity inside the geothermal field, researchers installed an eight-station seismic network and a seven-element small-aperture seismic array in 2015 in the vicinity of Tuscany's geothermal power plants (Figure 1). During the first 24 hours of recording, the array and the neighboring network stations recorded an M = 0.5 seismic event in the vicinity of the geothermal field of Bagnore. Since then, scientists have continued to record regular microearthquake activity.

The Challenge: Discriminating Natural from Anthropogenic Seismicity

The main challenge of the seismic array and network in the Mount Amiata area is to identify possible seismic events caused by human operations. The monitoring capabilities of the recording system permit a lowering of the detection threshold for local seismic events, determining, on very fine scales, the exact location of the earthquake's hypocenter, especially in the vicinity of the industrial operations, and calculating the physical focal mechanism of the seismic source.

Array techniques and relative location methods will be used for a precise hypocentral determination. Seismic events that are of volcanic, rather than tectonic, origin will be filtered out using polarization and spectral analysis. The crust, which is affected by simultaneous fluid extraction and reinjection, represents a complex system: In addition to the pore pressure variations on the single fault, thermal stresses and phase transitions get induced by the temperature difference of the cold fluid mixing into the hot rock volume. Therefore scientists are also conducting fluid-fault interaction studies and physical modeling of the area, which will allow them to estimate how much these effects contribute to inducing earthquakes.

Acknowledgments

The installation of the seismic array/network was realized in the framework of a student course on array seismology; we are therefore grateful to M. Caciagli, D. Famiani, A. Gattuso, T. Jacobi, J. Klose, C. Mascandola, M. Pastori, G. Petersen, F. Sandring, E. Türker, and our field technician R. Bauz. Marcello Cinci and Rebecca Spinelli (Enel Green Power) kindly supported logistics and site selection. The array course was cofinanced by the Earthquake Department of INGV. The seismic recording equipment was provided by the Institute for Geo- and Environmental Sciences of the University of Potsdam and the GFZ German Research Centre for Geosciences.

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Advancing Science Through Renovating AGU Headquarters

Hickok Cole Architects

The conceptual design for AGU's renovated headquarters in Washington, D. C., includes a rooftop solar array. By enabling the upgraded building to generate its own power and capture and treat its own water and waste, the project's solar cells and other features would make it the first net zero commercial renovation in the city.

When AGU's current headquarters was built in 1994, every effort was made to construct a facility that would not only serve the operations needs of the growing organization but also be a physical representation of AGU's science. Today, as that building's systems near the end of their useful life, AGU is preparing to renovate the 62,000-square-foot, five-story building.

Beyond replacing the building's aging and inadequately functioning heating, air conditioning, and plumbing systems, the renovation project presents an opportunity for AGU to embody its mission, vision, and goals. The renovation will help AGU advance the adoption of sustainable solutions rooted in science and position the scientific society and its members as leaders in implementing such solutions—an area of ever increasing importance. AGU has committed to making the renovation a showcase for Earth and space sciences and a "home away from home" for members visiting Washington, D. C.

Showcasing the Science

The current building celebrates the Earth and space sciences with such motifs as a representation of the solar system embedded in the adjacent sidewalk and layers of texture on the building facade mimicking density changes in Earth's interior. While the new building will follow that example through the selection of everything from the materials for the build-out to the artwork that will ultimately hang throughout the building, it will also push the goal even further.

Improving public understanding of Earth and space sciences and their contributions to solving the pressing problems facing humanity stands as one of the major goals of the renovation. In addition to numerous design elements intended to tell the story of Earth and space science, the building will include interactive public exhibits that showcase the research done by AGU members.

> The renovation will help AGU advance the adoption of sustainable solutions rooted in science.

Promoting Collaboration

AGU will also revamp the building's internal layout, work areas, and technologies to achieve flexible and adaptable workspaces that foster productivity, collaboration, and efficiency. These spaces will serve not only AGU staff but also AGU members, partner organizations, and the surrounding community. The new work environment will help AGU staff to better engage with members and provide improved service and programing. The building will become an amenity to both the Earth and space science community and AGU's neighbors in the Washington, D. C., region.

Striving for Net Zero

In keeping with AGU's intense focus on the Earth and space sciences, with many members researching environmental degradation and climate change, a mission-driven decision was made to strive for a net zero future for the building. A building that is net zero generates its own power and captures and treats its own water and waste. It operates with zero input of energy from the electric grid and of water from the municipal supply. It may generate enough energy from its clean, renewable power sources to put some energy back on the grid.

If achieved, the project will be the first commercial building net zero renovation in the U.S. capital. By pursuing that future vision with the inquisitiveness and open sharing of knowledge that is typical of scientific research, AGU intends to catalyze similar

approaches and designs in new and existing facilities throughout the city and beyond.

Construction Team Assembled

To help lead the organization on this journey, AGU has hired Hickok Cole Architects and the engineering design team Interface Engineering to develop the project's design. It also engaged general contractor Skanska as construction consultant. Other partners include MGAC as project manager and D. C.–based Stratacomm to handle communications.

AGU and these partner firms have solicited input on design and building elements at meetings with members, staff, and other stakeholders, including local water authorities, energy and environmental agencies, and neighborhood civic associations.

Next Steps

In March 2016, after this leadership team had completed many rounds of brainstorming, researching, and drawing up options for the remodeled building, AGU's Board of Directors approved a conceptual design for the project. That design has been presented to and reviewed by the Dupont Circle Conservancy, the D. C. Historic Preservation Review Board (HPRB), and the local Advisory Neighborhood Commission (ANC). It was also presented to the Dupont Circle Citizens Association (DCCA) and, in a town hall meeting, to people in the immediate community. The project has received support or approval from ANC, DCCA, the Conservancy, and HPRB, plus an overall positive response from the local neighborhood. With the building concept having been approved by the Board, AGU is now moving forward on other steps toward final approval and construction.

Because of D. C. zoning requirements, AGU must seek special exemptions from city regulatory agencies for some elements of the renovation. The final decisions on those exemptions are expected by late summer. AGU must also determine the final budget for the project and secure funding.

In late 2016 the AGU Board will consider for approval the cost, funding, and final design of the remodeled building. If the Board gives the go-ahead, construction will begin in early 2017 and last 12 to 18 months. During some of that time, AGU staff will relocate to a temporary office outside of the building. This move should have no impact on services to AGU members.

The upgraded building should open in time for tours by attendees of the 2018 AGU Fall Meeting, which will take place in Washington, D. C., and for AGU's centennial, which the organization will celebrate in 2019.

Find Out More

For additional information about the renovation, please see the project's website (http://building.agu.org), and read these posts on AGU's From the Prow blog (http://fromtheprow.agu.org): 7 June 2016, 28 March 2016, and 9 November 2015.

By **Chris McEntee,** Executive Director/CEO, AGU; email: agu_execdirector@agu.org

Can Solar and Space Physics Students Find Research Careers?

Baona/Istock

A new study examines what past solar and space physics doctoral graduates have gone on to do.

The field of solar and space physics is still young, arising during the space age from a broad range of fields. With the discovery of the solar wind and Earth's radiation belts, fields like cosmic ray physics, geophysics and geomagnetism, atmospheric science, radar engineering, and solar astronomy all gathered together under a single banner. In part because of its age, solar and space physics is still a relatively small field, with only 50–70 graduates per year in North America. But in the late 2000s, solar and space physics received a large influx of students that was not correlated with increased funding.

The 2013–2022 decadal survey by the National Research Council found that the career goals of these solar and space physics Ph.D. students are very similar to those in other science, technology, engineering, and mathematics (STEM) fields, with most desiring a research position. Unfortunately, other studies have shown that less than a third of STEM doctorates in general are able to find research jobs. There is therefore recent concern that given the lack of increase in funding for solar and space physics and the 2008 recession, new Ph.D. students in the field may not be able to find the research jobs they desire.

To investigate this potential problem, *Moldwin and Morrow* examined a cohort of Ph.D. students who graduated between 2001 and 2009 to determine whether they were able to find research careers. They compiled a database of 416 Ph.D. students whose dissertations were published during this period and then performed a literature search for publications by these individuals to determine their persistence in research.

The researchers found that four out of five Ph.D. recipients published in the year following their dissertation and that more than three quarters of these scientists continued to publish for another 4 or more years. They found differences between individual years, but overall, there were no discernible trends with time.

In addition, despite solar and space physics doctorates being more male dominated than STEM fields in general, the authors found that gender did not affect the likelihood that Ph.D. candidates would continue to publish after graduation.

Finally, the team also found that there was no relationship between department size and a Ph.D. candidate's likelihood of finding a research career.

However, there were still large differences between individual institutions. The authors suggest that it may be worth investigating whether factors such as financial support models, admissions, qualifying exam processes, and department culture could play a large role in determining the future careers of their students. (*Space Weather*, doi:10.1002/2016SW001382, 2016) **—Aleida K. Higginson, Freelance Writer**

Was the Recent Slowdown in Surface Warming Predictable?

From the early 2000s to the early 2010s, there was a temporary slowdown in the large-scale warming of Earth's surface. Recent studies have ascribed this slowing to both internal sources of climatic variability—such as cool La Niña conditions and stronger trade winds in the Pacific—and external influences, including the cooling effects of volcanic and human-made particulates in the atmosphere.

Several studies have suggested that climate models could have predicted this slowdown and the subsequent recovery several years ahead of time—implying that the models can accurately account for mechanisms that regulate decadal and interdecadal variability in the planet's temperature. To test this hypothesis, *Mann et al.* combined estimates of the Northern Hemisphere's internal climate variability with hindcasting, a statistical method that uses data from past events to compare modeling projections with the already observed outcomes.

The team's analyses indicate that statistical methods could not have forecast the recent deceleration in surface warming because they can't accurately predict the internal variability in the North Pacific Ocean, which played a crucial role in the slowdown. In contrast, a multidecadal signal in the North Atlantic does appear to have been predictable. According to their results, however, its much smaller signal means it will have little influence on Northern Hemisphere temperatures over the next 1 to 2 decades.

This minor signal in the North Atlantic is consistent with previous studies that have identified a regional 50- to 70-year oscillation, which played a more important role in controlling Northern Hemisphere temperatures in the middle of the 20th century than it has so far this century. Should this oscillation reassume a dominant role in the future, argue the researchers, it will likely increase the predictability of large-scale changes in Earth's surface temperatures. (*Geophysical Research Letters*, doi:10.1002/2016GL068159, 2016) **—Terri Cook, Freelance Writer**

What Makes Long-Runout Landslides So Mobile?

When earth, rocks, and debris on a slope give way, the resulting landslide can obliterate everything in its runout path. Landslides, like many geological disasters, are difficult to predict, but long-runout landslides—where a mass of earthen material travels unexpectedly long horizontal distances after a comparatively short vertical fall—are especially puzzling for scientists.

Existing models of long-runout landslides can reproduce observed slide events relatively well. But they can't explain why long-runout slides—with more than 1,000,000 cubic meters of material—experience a counterintuitive reduction of friction. Scientists have put forth many potential explanations: The debris might glide over a layer of trapped air, water could lubricate the slide's path, or friction-induced melting of ice or rock could ease the way for a large landslide. However, the occurrence of long-runout landslides elsewhere in the solar system makes any entirely air- or liquid-based explanation unlikely.

Here *Johnson et al.* use a soft particle code first presented by other researchers to elucidate the mechanism responsible for the reduced friction. The reprised, two-dimensional model approximates landslides down 45° slopes. The authors looked at variations in pressure on the ground within simulated landslides and found that sliding was more likely to occur when the pressure dropped below estimates of the overburden—the mass of material above the land at the base of the slide.

Jon White/Colorado Geological Survey

Long-runout landslides, like the 25 May 2014 West Salt Creek landslide with a volume of 30 million cubic meters of rock and a runout of 4.5 kilometers (about 7 times its fall height), have long puzzled scientists, but researchers are beginning to understand how wave processes within slides can reduce friction, allowing materials to travel unexpectedly long distances.

According to the researchers, sliding when the pressure on the ground is below measures of the overburden is characteristic of a process known as acoustic fluidization, where vibrations caused by sound waves traveling through the landslide affect friction. The authors conclude that acoustic fluidization could create the low friction necessary for long-runout landslides. (*Journal of Geophysical Research: Earth Surface*, doi:10.1002/2015JF003751, 2016) **—Kate Wheeling, Freelance Writer**

Curiosity Sends Curious Water Data from Mars

NASA/JPL-Caltech/MSSS

A portion of a photo snapped by NASA's Curiosity rover while traversing the Kimberley formation on its journey south toward the center of Gale crater. New spectroscopy data indicate that the water equivalent hydrogen makes up 1.5% to 2.5% of the weight of subsurface soils in this region.

On 6 August 2012, NASA's Curiosity rover landed on a Martian plain in the northern part of the 154-kilometer-wide Gale crater. Equipped with diverse instruments for imaging, sampling, and measuring, the rover immediately set to work, seeking clues to the planet's past climate as well as signs of chemicals necessary for life.

Curiosity collected data as it rolled slowly across the plain toward Aeolis Mons, a mountain at the center of Gale crater. One leg of the journey traversed an area known as the Kimberley formation, which features exposed layers useful for studying the Red Planet's past. *Litvak et al.* now report on estimates of water-associated hydrogen in Kimberley subsurface soil, specifically those made by the rover's Dynamic Albedo of Neutrons (DAN) instrument.

Scientists believe that much of the shallow subsurface of Mars—not just the polar caps—contains water in different forms, either water ice, physically absorbed water, or water bound in clay minerals. Funded by the Russian Federal Space Agency, DAN is a neutron spectrometer sensitive to the abundance of hydrogen in the Martian subsurface, regardless of what the hydrogen is bound to.

The hydrogen observed by DAN is assumed to be bound in water, based on the amount observed, soil samples, and similar observations from other Curiosity instruments. According to the authors, this indicates that the water equivalent of this hydrogen makes up 1.5% to 2.5% of the weight of subsurface soils in the Kimberley formation. This hydrogen is likely held in small quantities as adsorbed water in pores or in clay minerals formed during a warmer and wetter period of Mars's past.

DAN also found evidence of chlorine variations in the Kimberley formation. Both the water and the chlorine measurements made by DAN match well with those made by other Curiosity instruments for the same study site and by DAN for other similar sites. Chlorine is especially significant because variability of its bulk concentration might be related to volcanic activity, chemical weathering, water transport, hydrothermal activity—or perhaps the complex water history of an ancient lake.

As Curiosity drove southward across Kimberley, both water equivalent hydrogen and chlorine content derived from DAN were shown to decrease. The changes observed in DAN data correlate well to the observed bedrock stratigraphy of the Kimberley formation. Both water equivalent hydrogen and chlorine content also vary with depth. Curiously, DAN detected more water-associated hydrogen toward the surface than deeper down, opposite of what geological principles would predict. Further studies of Martian geology could reveal the reasons for these variations. (*Journal of Geophysical Research: Planets*, doi:10.1002/2015JE004960, 2016)

—Sarah Stanley, Freelance Writer

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INTERDISCIPLINARY

Research Fellowship — Climate Solutions (part-time, remote work)

Project Drawdown is a US-based research organization developing a book, open-source database, and digital platform describing how 100 existing technological, social, and ecological solutions, deployed at scale and in combination, can alter the composition of our atmosphere and help forge a path toward temperature decline. Co-developed by our coalition of scientists, scholars, policymakers, students, advocates and business leaders from across the globe, Project Drawdown represents the collaborative input of over 200 organizations and individuals worldwide.

We offer a small number of competitive fellowships designed to promote a new generation of climate leaders. Research Fellows will work with our senior research team to develop solution-specific models, technical reports, and recommendations for solutions.

Fellows in the 2016 Fellowship will build out the second phase of research, analysis, and modeling of Drawdown solutions. Research Fellows will evaluate and augment the initial research conducted by previous Drawdown Fellows, collect additional data as needed, revise and refine model methodology as needed, and integrate individual solution models. As in previous cohorts, 2016 Research Fellows will take part in a number of professional development opportunities providing practical tools and experience to enhance their career development.

We are recruiting for fellows with an interest in land use, biosequestration, forestry, building efficiency, transportation efficiency, material reduction, and related disciplines.

For detailed information and application instructions, visit: http://www.drawdown.org/researchfellows-2016

University of Basel

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The Department of Environmental Sciences at the Faculty of Science, University of Basel invites applications for a Professorship in Atmospheric Sciences (open rank).

We are seeking a scientist with a strong record of innovative and high-impact research in the broader fields of Atmospheric Sciences.
The successful candidate will help to develop and strengthen the division of Geoscience within the Department of Environmental Sciences (http://duw.unibas.ch).

Candidates applying are expected to demonstrate internationally recognized scholarly activities with a strong record of externally funded research. Preference is given to candidates who investigate the interactions between the atmosphere and the Earth's surface. Particularly encouraged to apply are candidates interested in either of the following research areas:

1) Atmospheric trace gas fluxes- and transport processes and their interaction with the biosphere, pedosphere and/or hydrosphere.
2) Feedback and feedforward mechanisms between climate, trace gasses, aerosols and energy.
3) Quantification of chemical conversion processes in the atmosphere.

The successful candidate is expected to teach basic courses in meteorology and climatology both at the undergraduate (in german and english) and graduate (in english) levels, and to contribute to the development of the degree programs BSc and MSc in Geosciences, in particular the major in geography and climatology, as well as the degree programs BA and MA in Geography.

The University of Basel is an equal opportunity and family friendly employer committed to excellence through diversity. To increase the number of women in leading academic positions, the University strongly encourages applications from women.

Application / Contact
Applications including letter of motivation, CV, list of publications, and a statement of research and teaching interests should be sent by e-mail as one pdf-document to Prof. Dr. Jörg Schibler, Dean of Faculty of Science, University of Basel, Klingelbergstrasse 50, 4056 Basel, Switzerland, at: dekanat-philnat@unibas.ch.

Please address requests for further information to Prof. Dr. Moritz Lehmann, Dean of Research (moritz.lehmann@unibas.ch).
The application deadline is 10 September 2016.

www.unibas.ch

NOTICE OF VACANCY
WASHINGTON STATE UNIVERSITY
Laboratory for Atmospheric Research
Department of Civil and Environmental Engineering
Voiland College of Engineering and Architecture
Position 55848

Washington State University, Department of Civil and Environmental Engineering and the Laboratory for Atmospheric Research (LAR) invite applications for a permanent 9-month tenure-track faculty position at the assistant to associate professor level on the Pullman campus with an effective start date from January 1, 2017 to August 16, 2017. This position is part of WSU's priority to build a diverse faculty; thus, female and minority candidates are strongly encouraged to apply.

Candidates are sought with expertise in numerical modeling related to air quality, atmospheric chemistry, and climate change at urban to regional scales. The successful applicant will help lead and grow the WSU AIRPACT air quality forecast system operation. The selected applicant will teach graduate and undergraduate air quality and environmental engineering courses, direct graduate student research, and develop a strong extramurally funded research program. The position requirements include:
1) expertise with urban to regional scale atmospheric chemistry models with applications to air quality, atmospheric chemistry, and/or climate change, 2) a record of research accomplishments demonstrated by peer reviewed publications and/or extramural grants, 3) demonstrated ability to work with diverse, interdisciplinary teams in a collaborative manner, 4) a record of outreach, mentoring, or teaching to diverse student populations, and 5) an earned Ph.D. or equivalent degree in a relevant engineering or science field. In addition, experience using remote sensing and in situ observations to evaluate and improve models and participation in the design and implementation of field campaigns is desirable.

Applicants should apply online at https://www.wsujobs.com by submitting the following: a cover letter, a detailed resume, a statement of research and teaching interests, and a list of five references with contact information. Screening of candidates will begin September 1, 2016, but applications will be accepted until the position is filled.

WASHINGTON STATE UNIVERSITY IS AN EQUAL OPPORTUNITY/AFFIRMATIVE ACTION EDUCATOR AND EMPLOYER.

Postcards from the Field

Hello, everyone,

Greetings from Kenai Fjords National Park. We are servicing one of our seismic stations (HOLG) for the Southern Alaska lithosphere and mantle observation network (SALMON) experiment across from Holgate Glacier. There's never been a more beautiful office-for-the-day!! #ilovemyjob

—Melissa Moore-Driskell (pictured), University of North Alabama; with **Doug Christensen** and **Carl Tape,** University of Alaska Fairbanks

View more postcards at *http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.*

Mark your calendar!

JpGU–AGU Joint Meeting 2017

20–25 May 2017

Makuhari Messe,
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More than 50 joint sessions presented
in English are expected

AGU

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AGU LEADER

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6 Week Until the Election

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- **1 August:** Ensure your AGU membership and section/focus group affiliations are current in order to be eligible to vote
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